Appendix F:
Photo Interpretation Mapping Conventions And Visual Key

USGS-NPS Vegetation Mapping Program
Voyageurs National Park, Minnesota

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Introduction

This document is a photo interpretation and visual key to map units for the Voyageurs National Park Vegetation Mapping Project. Its purpose is to:

- Provide a ground photo image for each map unit;
- Describe the link between each map unit and the U.S. National Vegetation Classification (USNVC);
- Provide visual examples of each map unit with aerial photographs and delineated overlays;
- Provide descriptions for the visual examples;
- Provide an area report for each map unit;
- Provide accuracy assessment results for each map unit.

This key does not attempt to show an exhaustive representation for all variations within each map unit; only the most common or significant representations are included herein. These should be sufficient to give the user a feel for the imagery and an understanding of the relationships between classification and mapping.

Organization to the Photo Interpretation Visual Key

This key presents descriptions and illustrations for every map unit used in the Voyageurs National Park Vegetation Mapping Project. Each map unit is presented in a uniform format on two to three pages. Each map unit section begins with a presentation of the map unit name and a representative ground photo of the map unit if available. A paragraph below the ground photo describes the link between the map unit and the vegetation association(s) within the USNVC. A general description is given of the vegetation association(s). For detailed descriptions of vegetation associations, refer to Section 6 of the main report, *Vegetation Descriptions of Voyageurs National Park*. Several 2 x 2-inch aerial photograph images follow. The images are scanned portions of the 1995 and 1996 color infrared (CIR) aerial photograph prints with the matching transparent interpreted overlays (Figure 1 of this document). These 2 x 2-inch images are of the same scale (1:15,840) as the aerial photographs. Each image reveals the photo interpreter's inked polygon outlines and map codes. A map code is made up of a map unit code (e.g. RP) and physiognomic modifiers if applicable (e.g. -1A2). The featured polygon is identified with the map code and a line pointing to it. The bottom left corner gives the date of photograph (month-year) and an approximate geographic location. With each image, a short explanation describes the map unit and its physiognomic modifier of the featured polygon. This description includes color(s) and texture(s), and when applicable, the coverage density and pattern, and height of the vegetation. Other information about the map unit or the polygon is also presented if it adds to better understanding or recognition of that particular map unit.

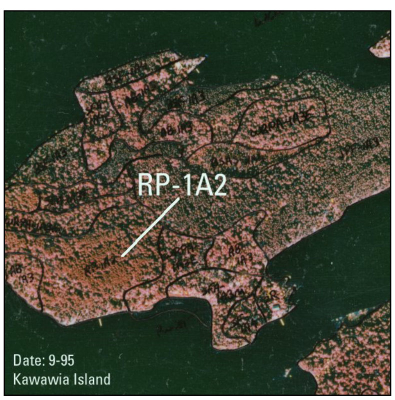


Figure 1. Image of aerial photo with interpreted overlay

Lastly, each map unit has an area report and results of the accuracy assessment. The area report includes the number of polygons, hectares, acres, and the average size. This information is also presented in the main report (Table 6). Accuracy assessment results for producers' and users' accuracy and the confidence intervals are also given. For map units where producers' or users' accuracy fall below the 80% standard, a general explanation is usually given identifying the primary error. Detailed information on the types of errors that occurred for any given map unit are presented in the main report (Table 7).

The map units are arranged according to ecological groups, that is, groups of types that share similar ecological processes (Faber-Langendoen 2000, in press). Twelve ecological groups were used to organize the types at Voyageurs, 6 wetland groups and 6 upland groups. These groups highlight the ecological diversity found at Voyageurs.

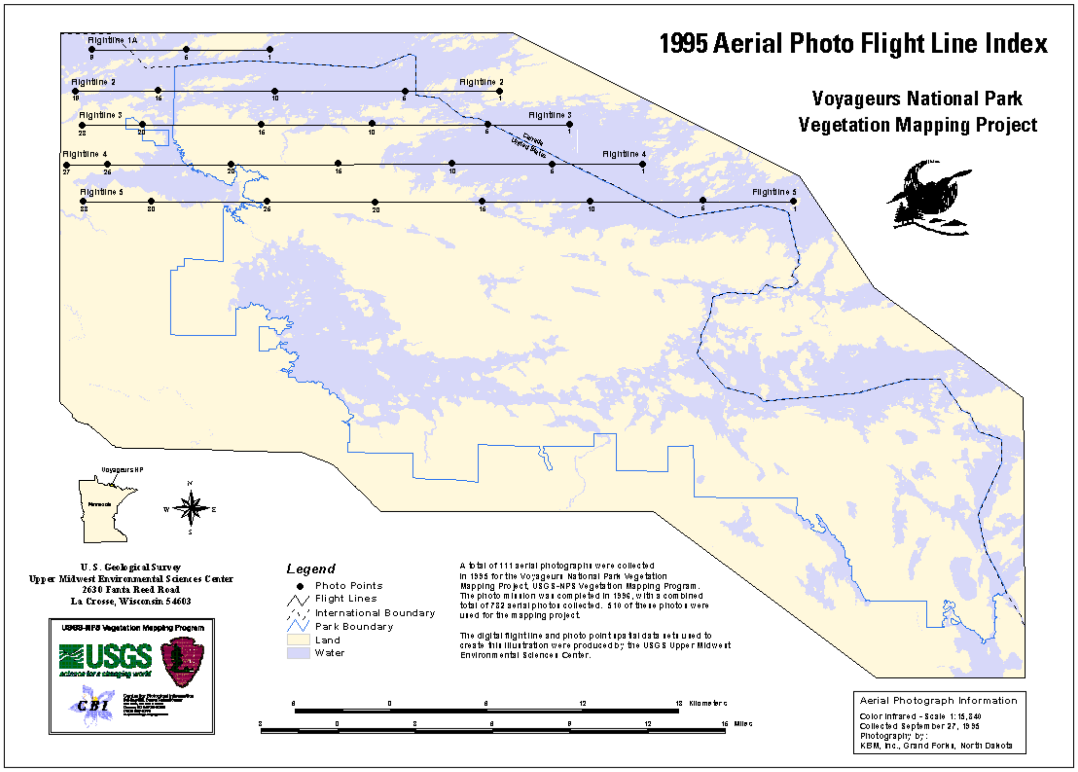
Aerial Photographs

KBM, INC (1604 S. Washington St., Grand Forks, ND 58201-6334) collected aerial photographs for a portion of the northern one-third of project on September 27, 1995. The remaining area was collected in 1996 (September 13, 14, and October 3). The photos were taken at a flight altitude of 7,920 feet above sea level with a Jena Link 15/2323 camera using Kodak Aerochrome Infrared 2443 film. The photo mission was designed to take photos with about 30% side lap (between each flight line) and 60% overlap (along each flight line). The scale of the CIR 9 x 9-inch transparencies is 1:15,840 (approximately 4 inches to one mile). Two sets of contact prints were produced from the transparency set (Figure 2). A total of 782 photos along 20 flight lines were collected. The photo mission covered the entire project area, which includes the entire park and environs (Figure 3). Only 509 of these photos were necessary to map the defined project area. The photo transparency set was used to interpret vegetation and land cover types using a stereoscope over a light table. The photo print sets were used for field reconnaissance, vegetation data collection, and map automation. An existing set of CIR photo prints, taken in the fall of 1988 at a scale of 1:12,000, were used as collateral information (see section 2.7 *Photo Interpretation* in the main report).

Figure 2. Example of an aerial photograph
(*example is not to scale*)

Color Infrared Film (CIR)

Vegetation reflects more infrared than visible light, and this helps subtle differences in physical characteristics of species to show up as large differences on CIR film. CIR imagery presents a “false color” picture that combines infrared reflectance with green and red visible bands. The differences in reflectance create differences in color that allow the photo interpreter to see the distinguishing features of different plant species and vegetation communities. Reflectance is influenced by structure of the canopy, the orientation of the plants and their leaves, and the thickness and pigment content of leaves. For example, needle foliage of conifers creates internal shadows and the leaves themselves reflect less infrared radiation than hardwoods. This gives them a darker appearance in the CIR than hardwoods such as oak and aspen (Hershey and Befort 1995).



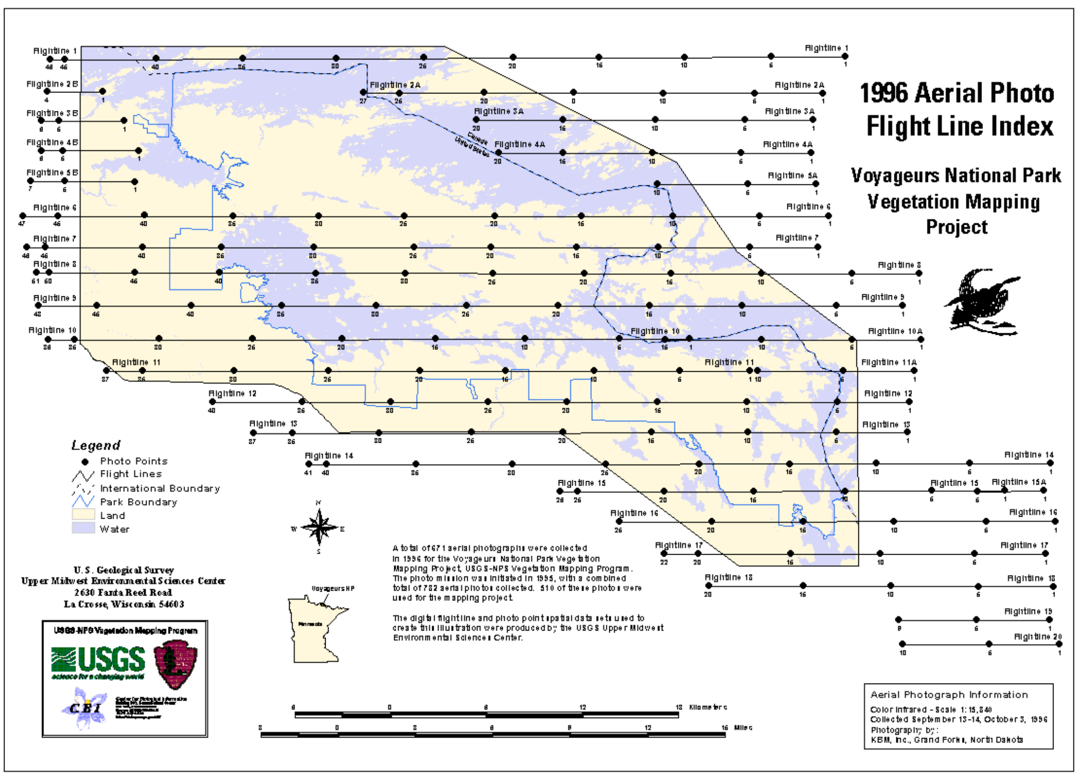


Figure 3. 1995 and 1996 Aerial Photographs of Voyageurs NP and Environs

Texture is also important to the photo interpreter for identification. For trees, texture is influenced by type and orientation of leaves, crown size and shape, and branch structure. An uneven canopy height will appear more broken than an even canopy. Similarly, trees having small crowns will appear a finer texture than trees that have large crowns. Depending on the tree species, the texture can be rough or smooth, fine, lacy, billowy, compact, or any number of other descriptors. These are imprecise terms, but nonetheless important visual elements of the imagery. In contrast, herbaceous vegetation, including wetland and upland communities, generally tend to appear much smoother in texture than forests or woodlands (Hershey and Befort 1995).

Color infrared photography is not consistent enough to allow a species or type to be described precisely. Film batch, printing process, sun angle, light intensity, shadow, and exposure can all affect the appearance of CIR photography (Hershey and Befort 1995). Thus, ground verification of every set of photos is imperative to successful interpretation.

The U.S. National Vegetation Classification

The U.S. National Vegetation Classification (USNVC) is a vegetation-based system that emphasizes natural and existing vegetation. The Nature Conservancy and the Natural Heritage Programs in North America developed the system out of conservationists needs to move from strategies focused on endangered species to a more comprehensive approach based on ecological communities. A standardized national classification of ecological communities was needed to implement such a strategy (Grossman et al. 1998). The system uses a combined physiognomic-floristic hierarchy. Table 1 of this document provides an example of the classification hierarchy.

Table 1. The USNVC's Physiognomic-floristic Hierarchy for Terrestrial Vegetation (from Grossman et al. 1998).

Level	Primary Basis For Classification	Example
Class	Growth form and structure of vegetation	Woodland
Subclass	Growth form characteristics, e.g., leaf phenology	Deciduous Woodland
Group	Leaf types, corresponding to climate	Cold-deciduous Woodland
Subgroup	Relative human impact (natural/semi-natural or cultural)	Natural/Semi-natural
Formation	Additional physiognomic and environmental factors, including hydrology	Temporarily Flooded Cold-deciduous Woodland
Alliance	Dominant/diagnostic species of uppermost ordominant stratum	Populus deltoides Temporarily Flooded Woodland Alliance
Association	Additional dominant/diagnostic species from any strata	*Populus deltoides – (Salix amygdaloides) / Salix exigua* Woodland

Vegetation Map Units and Their Link to the USNVC

Vegetation map units presented in this document are those defined by the mapping and ecological teams from the U.S. Geological Survey Upper Midwest Environmental Sciences Center and The Nature Conservancy (see section 2.5 *Creation of Map Units* in the main report). Many of the map units crosswalk to the USNVC at the association level, but a few do not. The USGS-NPS Vegetation Mapping Program promotes mapping at the finest level of the USNVC (the association level) when possible. However, not all important vegetation distinctions are visible on the photos through interpretation. Environmental conditions or diagnostic species that distinguish closely related types are often not discernible on the imagery. Thus, some map units are aggregates of vegetation associations and do not have a one-to-one relationship with USNVC's finest level.

In some instances, the imagery reveals different signatures for a single association. For example, the Black Spruce / Labrador Tea Poor Swamp Association may have a canopy composed primarily of black spruce in some stands, or may have black spruce sharing dominance with tamarack in other stands. The imagery reveals differences in the canopy dominance, so before the classifiers decided that this was one association, the photo interpreters mapped them separately. These map units are called phases of an association. They are not phases from a classification perspective, only from a mapping perspective. For a complete description of the relationships between vegetation map units and the vegetation associations see section *3.4 Map Units* in the main report.

Table 2 lists these vegetative map units and their relationship to the USNVC under the *Natural/Semi-natural Vegetation Map Units* section.

Other Map Units

Several map units were derived to describe ground features that do not meet the criteria for USNVC Natural/Semi-natural Vegetation. These map units represent Planted/Cultivated Formations within the USNVC (such as evergreen plantation and hayland/pastureland), and land use/land cover (LUC) classes (such as agricultural land, urban land, and water that is >16 h and <10% vegetated), were are derived from Level II of *A Land Use and Land Cover Classification System for Use with Remote Sensor Data* (Anderson et al. 1976). In addition, map units were created to map small upland islands that fall below the standard minimum mapping unit of 0.5 h. An exception was made to map these islands to 0.1 h. Using the USNVC to map the vegetation of these islands is not ideal from either a field or a photo perspective. Last, map units for bodies of water that are <10% vegetated and are <16 h in size were created to map 2 kinds of small natural ponds. Because of limitations in seeing submergent vegetation with CIR aerial photographs, some of these small ponds may indeed have >10% vegetation. In the case of error, it is recommended that these would best be described with the Midwest Pondweed Submerged Aquatic Wetland Association. Table 2 lists these map units and their relationship to the USNVC under the *Planted/Cultivated, Land Use/Land Cover, and Park Specific Map Units* section.

Table 2. Map units and related levels within the U.S. National Vegetation Classification or Anderson (1976) for Voyageurs National Park. Map codes are organized by Ecological Groups.

MAP UNIT CODE	MAP UNIT NAME	LEVEL
	Natural/Semi-natural Vegetation Map Units	
Bogs		
Treed Bogs		
BSB	Black Spruce Bog	Association
Shrub Bogs		
LBC	Black Spruce/Leatherleaf Semi-treed Bog	Association
LB	Leatherleaf Bog	Association
BBX	Beaver Basin Break-up Mosaic	Map Unit
Northern Shrub and Graminoid Fens		
Shrub Fens		
BBSF	Bog Birch-Willow Shore Fen	Association
LSF	Leatherleaf-Sweet Gale Shore Fen	Association
TF	Tamarack Scrub Poor Fen	Association
Graminoid Fens		
SPF	Northern Sedge Poor Fen	Association
Wet Meadows		
BJ	Canada Bluejoint Eastern Meadow	Association
SMX	Wet Meadow/Fen Mosaic/Complex	Map Unit

MAP UNIT CODE	MAP UNIT NAME	LEVEL
Marshes		
Emergent Marshes		
PM	Eastern Reed Marsh	Association
BM	Freshwater Bulrush Marsh	Association
CM	Midwest Cattail Deep Marsh	Association
WRM	Wild Rice Marsh	Association
DMX	Deep Marsh Mosaic/Complex	Map Unit
Rooted and Floating Aquatic Marshes		
PW	Midwest Pondweed Submerged Aquatic Wetland	Association
WL	Northern Water Lily Aquatic Wetland	Association
Northern Conifer and Hardwood Swamps		
Rich Hardwood Swamps		
BA	Black Ash-Mixed Hardwood Swamp	Association
WCBA	White Cedar-Black Ash Swamp	Association
Rich Conifer Swamps		
BSAS	Black Spruce/Alder Rich Swamp	Association
TA	Northern Tamarack Rich Swamp	Association
WCS	White Cedar-(Mixed Conifer)/Alder Swamp (rich soil phase)	Association
WCT	White Cedar-(Mixed Conifer)/Alder Swamp (peatland phase)	Association
Poor Conifer Swamps		
BSL	Black Spruce/Labrador Tea Poor Swamp (evergreen phase)	Association
BST	Black Spruce/Labrador Tea Poor Swamp (mixed phase)	Association
Northern Shrub Swamps		
DS	Dogwood-Pussy Willow Swamp	Association
AS	Speckled Alder Swamp	Association
Rock Barrens		
Treed Rock Barrens		
JPW	Boreal Pine Rocky Woodland (jack pine phase)	Association
JPM	Boreal Pine Rocky Woodland (mixed pine phase)	Association
JPL	Jack Pine/Lichen Rocky Barrens	Association
ABW	Mixed Aspen Rocky Woodland	Association
OW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (deciduous phase)	Association
JPOM	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (jack pine-oak phase)	Association
MPHW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (mixed pine-oak phase)	Association
Shrub and Herb Rock Barrens		
UBS	Boreal Hazelnut-Serviceberry Rocky Shrubland	Association
MGF	Poverty Grass Granite Barrens	Association
Northern White Cedar-(Hardwood) Forests		
WCU	White Cedar-Boreal Conifer Mesic Forest	Association
WCA	White Cedar-Yellow Birch Forest	Association
Northern Pine-(Hardwood) Forests		
JPAX	Jack Pine-Aspen Forest Mosaic	Map Unit
JPF	Jack Pine/Balsam Fir Forest	Association
WRPA	White Pine-Red Pine-Quaking Aspen-Birch Forest	Alliance
RP	Red Pine/Blueberry Dry Forest	Association
WP	White Pine/Mountain Maple Mesic Forest	Association
Northern Spruce-Fir-(Hardwood) Forests		
SFA	Spruce-Fir-Aspen Forest	Alliance
BSF	Black Spruce/Feathermoss Forest	Association
SF	Spruce-Fir/Mountain Maple Forest	Association

MAP UNIT CODE	MAP UNIT NAME	LEVEL
Boreal Hardwood Forests		
AB	Quaking Aspen-Paper Birch Forest	Alliance
PB	Paper Birch/Fir Forest	Association
AL	Trembling Aspen-Balsam Poplar Lowland Forest	Association
Northern Hardwood Forests		
BO	Northern Bur Oak Mesic Forest	Association
	Planted/Cultivated, Land Use/Land Cover, and Park Specific Map Units	
Planted/Cultivated Vegetation (USNVC)		
EP	Evergreen Plantation	Formation
PGCH	Perennial Grass Crops (hay, pastureland)	Formation
PGCS	Perennial Grass Crops with Sparse Shrubs (hay, pastureland)	Formation
Land Use/Land Cover (USGS - Anderson Level II)		
Developed Lands		
ACP	Cropland and Pasture	LUC II
ARB	Other Agricultural Land	LUC II
BLQ	Strip Mines, Quarries, and Gravel Pits	LUC II
UC	Commercial and Services	LUC II
UR	Residential	LUC II
UT	Transportation, Communications, and Utilities	LUC II
Lakes and Streams		
WLK	Lakes (>16 h)	LUC II
WS	Streams and Canals	LUC II
Small Islands and Natural Ponds (Park Specific)		
Small Islands		
SIG	Small Island with Grass (0.1 - 0.5 h)	Park
SIR	Small Island with Rock (0.1 - 0.5 h)	Park
SIS	Small Island with Shrubs (0.1 - 0.5 h)	Park
SIT	Small Island with Trees (0.1 - 0.5 h)	Park
Small Natural Ponds		
WBP	Water-Beaver Pond (<10% vegetated)	Park
WNP	Water-Natural Pond (<16 h, <10% vegetated)	Park

Photo Interpretation

Preparation of the aerial photographs for interpretation follows procedures of Owens and Hop (1995). The 1995 and 1996 CIR film transparencies were cut from rolls and covered with clear acetate overlays. The overlays were registered to the transparency photos and subsequently labeled with flight line and photo numbers.

Field reconnaissance was performed to learn, test, and verify photo signatures of vegetation types and other non-vegetated features (land use/land cover) and to establish a map classification. Once mapping protocols were established, photo interpretation and mapping proceeded.

Photo interpretation was performed using the 1995 and 1996 photo transparencies. Ground features were interpreted, and subsequently were delineated and labeled with map unit codes onto the photo overlays using a Bausch and Lomb Zoom 240 stereoscope over a light table. Each transparency photo was viewed with its matching stereo pair (adjacent photo) so images could be seen in 3-dimensions. To minimize edge distortion, interpretation was focused towards the center of each aerial photograph.

Texture, height, color, pattern, life form, and position in the landscape were all used in the decision making process of delineating polygons and assigning map unit codes. In addition to photo signature characteristics, the photo interpreter's knowledge of the environmental distribution of the types was used to help confirm the identity of the signatures. A standard minimum mapping unit of 0.5 h was applied. Small upland islands were mapped to 0.1 h. 509 aerial photographs of the 1995/1996 set were interpreted for the project.

With mapping vegetation types, a polygon is delineated to define a particular vegetation type. The polygon is attributed with a map unit code that represents the vegetation type. Conventionally, a polygon is not sub-divided because of physiognomic structural changes with the vegetation (e.g. density, height). However, extensive structural changes (e.g. large blowdown areas) within a map unit polygon were delineated separately. To attribute the physiognomic structure of the vegetation, a systematic string of modifier codes (see attribute section below) were added to map unit code (Table 2, e.g. DMX-2B, BA-1A4, WRPA-1A2M). Physiognomic modifiers are added (when applicable) to all vegetation map units.

During the onset of mapping, other maps were used to gain familiarity with vegetation characteristics. A map of Kabetogama Lake [*1988 Vegetation of the Kabetogama Peninsula, Minnesota. Unpublished map (1:24,000), Natural Resources Research Institute, Duluth, Minnesota. Funded by National Science Foundation Grant DEB-9119614]* and National Wetlands Inventory 7.5-minute quadrangle maps (U.S. Fish and Wildlife Service, St. Petersburg, Florida) were especially useful during the initial stages of photo interpretation.

Throughout the entire interpretation process, October 1988 CIR photographs were also viewed to better determine vegetation types. The 1988 photos, because they effectively captured fall colors in leaf canopies, were very helpful in revealing various distinctions not apparent on the 1995 and 1996 photographs. The primary characteristic that differed was that of color. Where changes in the vegetation occurred between the two sets of photographs, only characteristics on the recent set were used to determine the types.

Attribute Conventions for Map Unit & Physiognomic Modifier Codes

Through the process of interpreting the aerial photographs, polygons were delineated to capture the position of vegetation communities (USNVC types, as discussed previously) and land use/land cover features (such as roads and non-vegetated lakes). To attribute these polygons, map unit and physiognomic modifier codes were used for technical mapping purposes. The map unit codes represent the vegetation types and land features, and the physiognomic modifier codes represent the growth structure of the vegetation within a mapped polygon. These codes were later joined with a database table containing the definitions of these codes, thus incorporating the definitions into the spatial map. Descriptions to map unit codes and physiognomic modifier codes are listed on Tables 2 and 3 respectively of this document.

The following briefly explains the conventional practice for polygon attribution. The format uses a combination of alternating alpha and numeric codes. The result is a string of codes to describe in detail the features of a mapped polygon.

The attribute code begins with the **map unit code**, which represents either a vegetation type(s) or a land use/land cover feature. The map unit code is made up of 2 to 4 **alpha** characters. *Examples:*

WRPA, **JPW**, **DS**, **LB**, **CM**, **UR**

A series of **physiognomic modifier codes** follow the map unit code when applicable. A **hyphen** is placed between the map unit code and the string of physiognomic modifier codes. All vegetation map unit codes (codes describing USNVC types) receive physiognomic modifiers. *Examples:*

WRPA**-**, JPW**-**, DS**-**, LB-, CM**-**

The first physiognomic modifier code represents **Coverage Density**. It describes the coverage (a percent range) of the vegetation type that the map unit is representing within the polygon. Typically, the modifier defines the coverage of the higher plant life form (e.g. density of tree canopy, not density of tree canopy and shrub layer). The modifier is a single **numeric** code. All vegetation map unit codes receive this modifier. *Examples:*

WRPA-**1**, JPW-**2**, DS-**2**, LB-1, CM-**1**

The second physiognomic code represents **Coverage Pattern**. It describes the pattern or distribution of the vegetation type that the map unit is representing within the polygon. Like the density modifier, the pattern modifier typically defines the growth pattern of the higher plant life form. This modifier is a single **alpha** code and follows the Coverage Density numeric code. All vegetation map unit codes receive this modifier. *Examples:*

WRPA-1**A**, JPW-2**B**, DS-2**C**, LB-1A, CM-1**C**

The third physiognomic code represents **Height**. It describes the average height of the woody terrestrial vegetation type that the map unit is representing within the polygon. In forest and woodland cases where a super-canopy exists of >25% cover, the modifier describes the height of the super-canopy tree (to indicate age of stand) and not the average height of all trees. There is no representation within the map code of whether the height is indicative of average or supra-canopy. The modifier is a single **numeric** code and follows the Coverage Pattern alpha code. Only map units representing vegetation types under the USNVC Forest, Woodland, Shrubland, and Dwarf-shrubland Formation Classes receive this modifier. *Examples:*

WRPA-1A**2**, JPW-2B**4**, DS-2C**5**, LB-1A**6**

The last physiognomic modifier code represents **Dominance/Co-dominance**. It describes the degree of mixes between evergreen and deciduous trees (and shrubs for some woodland types) within a polygon. The modifier is a single **alpha** code and follows the Height numeric code. All map units representing vegetation types under the USNVC Mixed Evergreen - Deciduous Forest Formation Subclass receive this modifier. In addition, the BST & WCT map units (deciduous mixed phases of true evergreen forest types), and the MPHW* & JPOM map units (evergreen mixed phases of a true deciduous woodland type) are the exceptions. Throughout the mapping process, the vegetation types represented by these map units were thought to be true mixed evergreen-deciduous vegetation types. After further analysis of vegetation data, it was determined that these vegetation types were actually phases of either true evergreen or deciduous forest or woodland types. The modifiers were retained to provide additional information about the vegetation and polygon. *Examples:*

WRPA-1A2**E**, BST-1A4**M**, MPHW-2B4**D**

* all MPHW-XXXE codes were globally changed to another map unit code (JPM-XXX)

Table 3. Key to Physiognomic Modifier Codes

Coverage Density (all vegetation map units)
1 - Closed Canopy/Continuous (60-100% coverage)
2 - Open Canopy/Discontinuous (25-60% coverage)
3 - Dispersed-Sparse Canopy (10-25% coverage)
Coverage Pattern (all vegetation map units)
A - Evenly Dispersed
B - Clumped/Bunched
C - Gradational/Transitional
D - Regularly Alternating
Height (forest, woodland, shrubland, & dwarf-shrubland map units)
1 - 30-50 meters (98-162 feet)*
2 - 20-30 meters (65-98 feet)
3 - 12-20 meters (40-65 feet)
4 - 5-12 meters (16-40 feet)
5 - 0.5-5 meters (1.5-16 feet)
6 - <0.5 meters (<1.5 feet)
Dominance/Co-dominance (forest & woodland map units, evergreen-deciduous mix)
D - Deciduous dominant 60-75%, evergreen 25-40%
E - Evergreen dominant 60-75%, deciduous 25-40%
M - Deciduous/Evergreen co-dominant, each 40-60%
** Height code "1" was not used for VOYA vegetation mapping*